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Research article

Critical success factors and collaborative governance mechanism for the transformation of existing residential buildings in urban renewal: From a social network perspective

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ABSTRACT

The renovation of urban residential buildings in the context of urban renewal presents social challenges due to the involvement of diverse stakeholders and complex interest relations. This study identifies 28 critical success factors (CSFs) and 9 stakeholders, drawing insights from literature and on-site research of 45 old residential renewal projects in Jiangsu Province, China. Employing social network analysis, the intricate interplay between CSFs and stakeholders is explored, emphasizing the imperative for collaborative governance and elucidating governance mechanism principles. Focusing on stakeholders' resource contributions to transformation projects, the study devises a collaborative governance mechanism based on the specific types of resources required to support each CSF. This approach ensures that CSFs receive the necessary resources, enhancing project success. The paper concludes by outlining nine governance mechanisms and their implementation paths, anchored in the relationships between 13 CSFs and their respective stakeholders.

1. Introduction

Urban renewal is a general trend for urbanization to enter the stage of medium- and high-speed development, and an inevitable requirement for promoting high-quality urban development. Urban development in developed economies has gone through the process of upgrading from new construction to stock renovation, and urban renewal has gradually shifted from initial physical renewal to multi-dimensional renewal of physical, economic, social and environmental dimensions, which has become the dominant mode of urban construction [1,2]. There are a wide variety of types and contents of urban renewal projects, but large-scale and extensive renovation projects usually take place in existing residential buildings [3]. In China, for example, according to China's 14th Five-Year Plan, China will complete the renovation of 160,000 old neighborhoods between 2021 and 2025, involving approximately 4 billion square meters of floor area. Compared with other types of urban renewal projects, the renovation of existing residential buildings involves complex stakeholders. The renovation is a redistribution and reorganization of the original pattern of interests, and it is easy

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to cause various conflicts due to the irrationality of the power and interests of all parties, which can lead to the failure of the renovation project or even cause serious social problems.

In order to reduce the problems highlighted in the renovation of existing residential buildings, many scholars have studied the stakeholders, crucial success factors (CSFs) and collaborative governance mechanisms of renovation projects [4–8]. Liang X et al. [9] developed a 2-mode social network model to reveal the path of stakeholder influence on project success, providing the basis for stakeholder management and control of critical factors. But existing research on collaborative governance mechanisms remains at the level of framework analysis and construction. There is still a lack of studies that refine CSFs through field research on a broad range of renovation projects with substantial numbers, and specifically target the construction of governance mechanisms by focusing on the key subjects and carriers of collaborative governance-resource collaboration. Therefore, this paper proposes that literature research should be combined with multi-case field studies to identify stakeholders and CSFs in regional renovation and transformation. The relationship between these stakeholders and CSFs will be examined using a 2-mode social network model. Through analyzing the CSFs that are jointly promoted or influenced by stakeholders, resources requiring collaboration can be identified, enabling the systematic and effective design of collaborative governance mechanisms. The basic logic of the study is shown in Fig. 1.

The remaining sections of the paper are structured as follows. The second section presents a literature review encompassing CSFs, stakeholders, and collaborative governance, aiming to pinpoint knowledge gaps in this domain. In the third section, the research methodology is outlined. Moving to the fourth section, a 2-mode social network analysis (SNA) is established, featuring 28 CSFs and 9 stakeholders as network nodes identified and optimized through literature research and field studies involving 45 old residential renewal projects in Jiangsu, China. The 2-mode SNA method is then applied to analyze the characteristic indicators of CSF and stakeholder networks, along with assessing the influence of stakeholders on the CSFs. Finally, the paper concludes with the design of a collaborative governance mechanism based on the outcomes of the 2-mode SNA.

2. Literature review

2.1. Literatures on CSFs of existing residential building renovation project

Since the initiation of urban renewal in European and American countries in the 19th century, urban redevelopment has progressively advanced globally in various forms. The identification of CSFs forms the foundation of research and practice in renovation and transformation. Scholars primarily employ methods such as case analysis, survey analysis, literature review, and model analysis to study these factors. As CSFs are closely related to the renewal organizational models, the study of CSFs has also undergone an analytical and exploratory process under different contexts, including government-led, market-driven, and multi-stakeholder collaborative urban renewal scenarios [10]. Based on the fact that CSF identification is the foundation of transformation research and practice, scholars have mainly adopted case studies, survey analysis, literature analysis and model analysis to conduct research. Since CSFs are closely related to the development stage of socio-economic environment, this study only reviews the relevant studies in the last five years. Based on a case study, Weinsziehr et al. [11] suggested that the success of a renovation project should focus on the owner's willingness to renovate, that the best sustainable renovation decisions should be recognized by all stakeholders, and that the main factors hindering renovation are the investment in upgrading and the renovation value of the old building. Liang et al. [10] identified 28 CSFs for renovation projects from five dimensions including economics, building information and environment, social culture, technology, and policy criteria, including cost, investment target, existing built environment, and existing building conditions. Jagarajana et al. [10] summarized eight categories of CSFs for successful implementation of renovation projects through analyzing

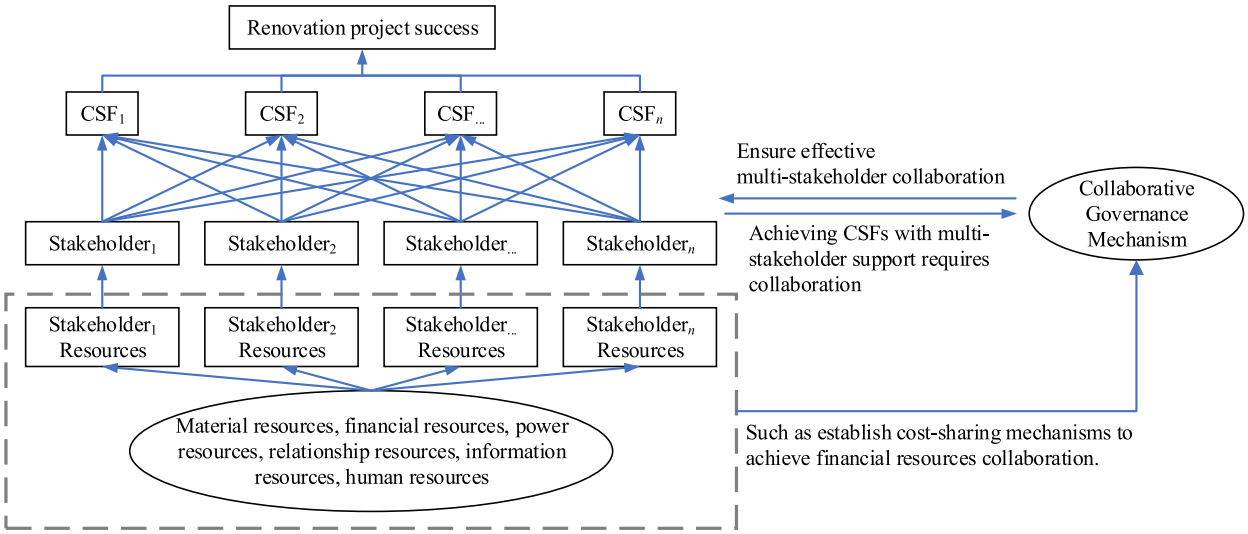

Fig. 1. Research logic of the study.

dozens of renovate literature: financial resources, green building knowledge, policy support, quantification of green development, green awareness, communication and communication, internal leadership, green technologies and materials. He et al. [12] constructed a theoretical model of renovation intention with reference to the extended theory of planning behavior, and tested the theoretical model by structural equation modeling (SEM) to obtain that the most important factor influencing residents' intention to renovate is policy factors, followed by cognitive, behavioral, subjective normative and perceived behavioral control of renovation. Zhang et al. [13] divided CSFs into two categories, internal and external, and found that internal factors are mainly interest drivers and social capital, while external factors are mainly related to institutions and the level of community governance. Based on the theory of multiple co-governance, Yu et al. [14] used the DEMATEL method at the government, resident, enterprise, and community levels respectively to conclude that the CSF affecting the transformation are laws and regulations, inter-subjective collaboration, etc.

In summary, scholars have studied the key success factors for renovation of existing residential buildings, which provides the basis for this study.

2.2. Literatures on stakeholders and collaborative governance for renovation of existing residential buildings

Stakeholders in the renovation of existing buildings are those who have a vested interest, directly or indirectly, in the operation of the building and in the outcome of future renovation projects [15], which can generally be divided into private users of the residence, the management as a public sponsor and private sponsors [5,16,17]. Based on the perspective of interest claims, Fang et al. [16] divides stakeholders in renovation into two categories: those with self-sustaining needs, such as residents of the renovation area, social organizations, technical experts, and enterprises, and those who focus on public interests, such as the government or public organizations. Andrew [18] further refines this into government authorities, public enterprise units, building ownership units and individual owners, property service companies, industry associations, and technical service agencies. Liang et al. [10] identified 13 stakeholders of green transformation in China, and their results show that the most important ones are owner/client, property manager, designer and government. Huang et al. [9] further refines it into government, design and construction companies, heating companies, residents, and financing companies.

The United Nations Commission on Global Governance defines "collaborative governance" as the sum of the many ways in which individuals and various public or private institutions manage their common affairs, emphasizing the problem-solving-oriented practice of public administration with the full participation of interested and affected stakeholders and shared responsibility across boundaries [19]. Collaborative governance, as an effective form of joining together various organizations to solve complex public problems, has been widely used by countries in a variety of policy settings such as public health, education, environmental protection, and resource management. As a livelihood project of the government, the renovation of existing residential buildings involves the interests of multiple subjects such as the residents, government and the society. Collaborative governance can not only realize fine community governance and create a good cooperation environment for multiple subjects, but also help improve the quality of the city, thus becoming an inevitable choice for the renovation and governance of existing residential buildings [20]. Zhu et al. [21] constructed a collaborative governance mechanism for renovation in 3 aspects: benefit protection, organizational reengineering, and operational optimization, and proposed a path to improve institutional arrangements, strengthen inter-governmental collaboration, establish social enterprise participation channels, and increase the level of substantive participation of residents. Wang et al. [20] constructed a theoretical framework for the linkage of "government, society and market", and proposed the path and countermeasures to improve the system design, promote the transformation of "residential area planning" to "community planning", enhance the community autonomy power, and realize the expansion of "bureaucratic management" to "collaborative governance". Based on the analysis of the renovation problem, Song [22] proposed collaborative governance countermeasures in terms of actively guiding residents' participation, giving full play to the government's macro-control role, promoting the establishment of relevant social organizations, and establishing a mechanism for collecting and using funds in a categorical manner. Xu et al. [23] developed an optimal decision model that can help government managers to rationalize their budgets and provide a way to promote multiparty participation to achieve optimal improvement strategies.

In summary, a collaborative stakeholder governance model with a multi-party partnership orientation, more emphasis on community participation and social equity, and more integrated and diversified connotations will be the development trend of urban renewal [24], but how to build and realize a collaborative governance mechanism for transformation to guarantee the success of the project still needs to be further explored.

2.3. Knowledge gap

Existing research on the collaborative governance of CSFs and stakeholders for retrofitting existing residential buildings has been conducted in some depth, but there is less systematic research on the multiple and complex relationships between stakeholders and CSFs. What's more, there is no further analysis of the stakeholders and their resources that need to be involved for each CSF to be reached. Existing research cannot clearly reveal what the best way for collaborative governance of stakeholders and how it can be achieved. Therefore, knowledge gap can be further determined as follows.

CSFs for the renovation of existing residential buildings is critical to determine the best way of collaborative governance, but there have been no in-depth studies. The research perspective based on social network theory explains social behavior in a holistic manner under a set of relationships and bonds formed by established social actors and treats the social network system as a whole. Using social network theory to study the operational relationships and role positioning of multiple stakeholders in the renovation process of existing residential buildings, and to optimize the allocation of responsibilities, rights and resources, the social problems in the

renovation process can be solved more effectively. How to construct an analytical model, based on the study of the relationship between stakeholders' promotion of CSF, to identify the stakeholders and their resources needed to achieve each CSF, so as to design an appropriate governance mechanism to ensure the achievement of the CSF and ultimately achieve the goal of successful renovation is an urgent issue to be studied.

3. Research methodology

Social networks can be categorized into unimodal and bimodal networks based on the characteristics of the set of actors and the properties of the links between actors. A bimodal network is a measure consisting of two actor sets or one actor set and one event set [25]. In previous studies, SNA has been used primarily in stakeholder analysis to identify stakeholders and analyze their priorities, influence, clusters, and other attributes. However, renovation CSFs are often neglected in the analysis of stakeholder governance structure relationships and lack an objective multidimensional and comprehensive analysis. The whole life cycle of existing residential building renovation projects involves multiple stakeholders and is in a complex social network environment, with various factors forming a network of relationships with the stakeholders as they interact with each other throughout the project life cycle. Therefore, confirming the relationship between them is the basis for the subsequent study of the influence of relevant governance subjects, power distribution, etc., and has a key role in establishing a reasonable and scientific governance mechanism. Therefore, a 2-mode SNA method is applied in this study, and the study is carried out according to the steps and methods as follows.

Step 1. Identify key stakeholders and CSFs at each stage of the project life cycle

Since the stakeholder composition and CSFs of urban renewal projects varies in countries with different institutional, socio-economic, and cultural and natural environmental conditions, the list of stakeholder composition and CSFs for each stage of the project life cycle can be initially determined based on the literature research, and then revised and supplemented through the study of typical cases in the study area.

In order to ensure the scientificity and reasonableness of CSF, an effective optimization method is also needed to further screen the CSF. Rough set theory can reasonably deal with imprecise, incomplete, and uncertain sample information by judging the relative degree of deviation of the indicators [26]. The intrinsic connection between the indicators can be identified from the small sample data and the indicators can be simplified, so as to ensure the simplification of the indicators without affecting the original classification and evaluation results. When the relative deviation of the indicators is greater than 90%, the indicators are simplified [27]. Therefore, this paper adopts rough set theory to screen and optimize the initial CSF.

Step 2. Construction of social network model

The collaborative governance of existing residential building renovation projects involves all stages of its life cycle, and different stakeholders have different power, status and roles in different stages, so the governance organization structure is dynamic. Thus, this paper intends to construct two categories of 2-mode network from the overall perspective of project life cycle and the process perspective of each stage of life cycle.

(1) Node determination of Bimodal social network

The identified key stakeholders are used as bimodal social network actor nodes and the optimized CSFs as event nodes.

(2) Construction of the adjacency matrix

Node relationships in 2-mode social network analysis can be defined in different ways, such as degree of cooperation, information sharing potential and support [28]. Depending on the type of relationship, different meanings can be used to define the value of connections, such as closeness of collaboration, degree of influence, and decision-making power [29]. When there is a strong interaction between nodes, the connection value is high. In order to minimize the influence of the subjective preferences of the dominant participants, and considering that judging requires more specialized theoretical knowledge and the number of relationships to be judged is large, the questionnaire survey should not be conducted by distributing a large number of questionnaires, and the Delphi method is appropriate for judging the relationships. In this paper, a binary square matrix is used to represent the relationship between network nodes, i.e., major stakeholders, and CSFs. If the nth stakeholder S_n has a direct influence relationship on the mth CSF - C_m, then the nth row and mth column in the matrix takes the value of 1, otherwise it is 0.

(3) Model visualization and analysis of key indicators

The main stakeholder-CSF adjacency matrix is substituted into the UCINET model for model visualization, and the 3 main indicators of the 2-mode social network are analyzed: degree centrality, intermediary centrality, and proximity centrality. Higher degree centrality indicates a more important position in the network; intermediary centrality reflects the interrelationship between two non-adjacent nodes in the network and the degree of dependence on other nodes in the network; proximity centrality indicates the proximity of the distance between actors in the network to other actors.

Step 3. Design of collaborative governance mechanisms

Stakeholder collaborative governance mechanism is designed based on the centrality indicator results of the SNA for full project

lifecycle of existing residential building renovation project and SNA for each phase of the lifecycle. This ensures that CSFs, which require the support of multiple stakeholders, are achieved, thus achieving project success.

4. Construction of 2-mode network model

4.1. Determination of network nodes

4.1.1. Stakeholder identification

Based on the research results of existing literature, 10 major stakeholders are initially identified, and then combined with the statistical analysis of 45 typical old residential renovation projects in Jiangsu, China, 9 major stakeholders are selected as shown in Table 1.

4.1.2. Determination of CSFs

(1) Identification of CSFs

Based on the available literature, 29 major stakeholders are initially identified, and then adjusted to 31 by combining the statistical results of 45 typical old residential community renovation project research questionnaires in Jiangsu, China, as shown in Table 2. These cases are summarized from the research results of the Science and Technology Plan Project (No. 2017-R1-002) of the China Ministry of Housing and Urban-Rural Development. The case selection principles during the project research primarily included (1) the cases being exemplary, (2) having replicable logic, and (3) being able to reasonably utilize research resources.

(2) Optimization of CSFs

This study employs rough set theory for the optimization and reduction of CSFs. Compared to other methods, rough set theory demonstrates superior capabilities in data knowledge extraction, particularly in dealing with imprecise, incomplete, and uncertain sample information. Additionally, rough set theory can effectively extract dependency relationships between indicators from small sample data while reducing redundant indicators and constructing simplified indicator sets. Importantly, indicator reduction in rough sets ensures the removal of redundant indicators without compromising the accuracy of the original classification and evaluation results.

The indicator reduction based on rough set theory aims to eliminate irrelevant or unimportant indicators while maintaining the classification capability of the knowledge base. Within this theoretical framework, assuming U is a finite set of objects, R is a set of indicators, and P is a cluster of equivalence relations defined on U. If after removing a relation R from P, the partition of equivalence classes remains unchanged, i.e., $IND(P \setminus \{R\}) = IND(P)$, then R is considered unnecessary in P; otherwise, R is deemed necessary. The union of all necessary relations in P forms the core of P, representing the set of indicator characteristics that cannot be eliminated during the indicator reduction process. If P and Q are two equivalence relation clusters on U, and $Q \in P$, if removing any relation from Q changes the partition of equivalence classes generated by P, i.e., $IND(Q) = IND(P)$, then Q is considered a reduction of P. Rosetta software is a mathematical analysis tool based on rough set theory, integrating various data preprocessing algorithms and common reduction rules of rough sets. The software incorporates several data preprocessing methods, such as data completion, data discretization, and the genetic algorithm for indicator reduction in rough set theory. Therefore, this study utilizes Rosetta software based on rough set theory for the optimized reduction of CSFs.

We selected and invited a total of 20 experts from various backgrounds, including universities, research institutions, design firms, property management companies, and consulting agencies. Following the five-point Likert scale rating rule, these experts assessed the importance of CSFs at different stages of the renovation project life cycle, thereby establishing a decision table $S = (U, R, V, f)$. Where $U = \{x_1, x_2, \ldots, x_n\}$ represents the sample data collected through questionnaire surveys, i.e., the domain. $n = 20$ denotes the 20 experts,

Table 1
Stakeholder identification for old residential renovation projects in urban renewal.

Code	Stakeholders	Definition	Source
S_1	Government	Government functional departments related to the renovation	[5,10,16]
S_2	Renewal area owners	Owners of existing residential buildings.	[17] [10] [0]
S_3	Community	Residents' organizations, including community self-governance organizations, owners' committees, etc.	[9,10,16]
S_4	Property management company	Service companies engaged in property management business of existing residential buildings before and after renovation.	[9,10,18]
S_5	Design company	Design companies that undertake the design of renovation projects.	[9,15]
S_6	Evaluation agency	A third-party service provider engaged in professional consulting and pre- and post-renovation project evaluation.	[9,10]
S_7	Construction company	Contractors undertaking construction of renovation projects.	[9,10]
S_8	Financial institution	Financial organizations that provide financing support for renovation.	[10,15]
S_9	Indirectly affected residents	Tenants in the renovated area and residents indirectly affected in the surrounding area.	[9,16]

Table 2
CSF identification results of old residential renewal projects.

Decision-making phase	Critical success factor	Factor description	Source
Investment decision phase (C_1)	Renewal cost (C_{11})	The full life cycle cost of the renewal project, including construction cost, operation and maintenance cost.	[11,12,30]
	Awareness of renewal (C_{12})	Stakeholders' awareness and perceptions of renewal and renovation.	[30,12,29]
	Related policies and regulations (C_{13})	Policies and regulations related to the renewal and renovation of old residential areas formulated by government departments.	[10,30,14]
	Residents' willingness for renewal (C_{14})	The willingness and demand of the owners for renewal and renovation.	[11,12,30]
	Financing method (C_{15})	The source of funds or channels for the renewal and renovation.	[10,11,14]
	Investor's return (C_{16})	Return on investment for parties invested in renewal projects.	[12–14]
Design phase (C_2)	Renewal and renovate diagnosis (C_{21})	Diagnose the performance and function of old residential buildings through on-site investigation and related testing methods, determine the potential and value of renewal and renovation, and provide the basis for the design of renewal and renovation plans.	[11,31]
	Building energy consumption (C_{22})	The energy consumption of the envelope, air conditioning and heating, lighting system and domestic hot water designed before and after the renewal.	[10,32]
	Design team professional competence (C_{23})	The composition, level or ability of professional design staff for renewal and renovation projects.	[10,32]
	Feasibility of design solutions (C_{24})	Whether the renewal design meets the renewal objectives, its economic, technical, social and environmental assessment is feasible, etc.	[10,30]
	Renovate measures(C_{25})	Main contents and measures in the renovation program, such as building envelope, facade, doors and windows, energy-saving renovation, site renovation, water system and electrical system renovation, etc.	[10,30,33]
Construction phase (C_3)	Level of disturbance caused by construction (C_{31})	The impact of the construction process on the daily life of the owners, tenants and merchants in the old residential area.	[10,30,33]
	Environmental protection degree during construction process (C_{32})	Measures taken by construction enterprises to ensure green construction, including measures to prevent air pollution, noise control measures, sewage treatment measures, etc.	[10,30]
	Construction period (C_{33})	Duration and schedule of renewal project.	[10,30]
	Construction team professional competence (C_{34})	The composition, level or ability of professional construction personnel for renewal and renovation projects.	[11,30]
	Construction project management (C_{35})	Construction companies' control of the quality, schedule, cost, and management of safety, information, and contracts of renewal projects.	[10,30]
	Technical feasibility of construction (C_{36})	Feasibility of the construction technology plan for the renewal project.	[10,30]
Post-modification evaluation phase (C_4)	Validity of post- modification evaluation system (C_{41})	Reasonableness of assessment index and weight determination, standardization of assessment process, standardization of assessment system and reliability of assessment results after updating.	[10,30]
	Demonstration effect of modification (C_{42})	The degree of influence that the renewed residential areas bring to the surrounding old residential areas in terms of willingness to transform, perceptions, etc.	[10,30]
	Management of assessment data(C_{43})	Management of basic data for post-renovation evaluation, such as performance monitoring data before and after renovation of old residential areas, and historical data for predicting investment returns.	[10,30]
	Satisfaction with modification (C_{44})	Stakeholders' satisfaction with the economic, environmental and social benefits of the renovation project.	[10,12]
	Degree of improvement (C_{45})	The degree of improvement of the specified evaluation indicators before and after the renovation is assessed according to the renovation evaluation criteria established by the relevant management department.	[30,12]
Operation and maintenance phase (C_5)	Site maintenance (C_{51})	Maintenance of the ecological environment, green land and public space around the residential area after renewal and renovation.	[5,12]
	User behavior (C_{52})	Update the behavior of residential area owners, tenants and other residents in the use of air conditioning, lighting, etc. after the renovation.	[12,15]
	Information management technology (C_{53})	Updating the inspection technology, information technology platform and other related information management technology in the process of operation and maintenance of the renovated residential area.	[30,12]
	Equipment and facility maintenance (C_{54})	Operation and maintenance of residential parking facilities, barrier-free facilities, HVAC equipment, energy-saving equipment, etc. after upgrading and renovation.	[10,30]
	Operational performance stability (C_{55})	The performance stability of residential buildings equipment and facilities after renovation in daily use and energy utilization.	[6,33] [12,14]
	Property management level (C_{56})	The management ability of property management enterprises and the advantageous services they can provide to the renewed residential areas.	[30,31]

R is the finite set of indicator, $R = \{r_1, r_2, \ldots, r_m\}$; m is the number of CSFs corresponding to each stage of the project lifecycle, and $V = \{v_1, v_2, \ldots, v_m\}$ is the value range set of indicator R, where v_i represents the value range of r_i. In this study, experts used a five-point Likert scale rating rule (5 for most important 1 for least important) to rate the importance of CSFs, so $v_i = \{1, 2, 3, 4, 5\}$. f is the

information function, where $f = U \times R \rightarrow V, f(x_i, r_j)$. Taking lifecycle stage C1 as an example, the decision table can be organized as shown in Table 3.

The obtained decision table is imported into the Rosetta software for data preprocessing, aiming to eliminate or complement any incomplete data. It is worth noting that due to the careful screening of the questionnaire data in this study, no data that needed to be completed or deleted were identified during the data processing stage. Subsequently, the software's built-in genetic reduction algorithm is employed to perform indicator reduction on the preprocessed data. The specific process is as follows: first, calculate the equivalence class relation set of conditional indicators in the decision table, denoted as $IND(P), P \in R$. Utilize rough set theory's indiscernibility relation to determine which conditional indicator constitute the relative reduction of the conditional indicator set R. If there are conditional indicator not belonging to the relative reduction, no reduction is applied to those indicators. Conversely, if there are relative reductions of conditional indicator belonging to set R, further judgment is made on whether these indicators should be simultaneously reduced or only some of them. Calculate the importance of each evaluation criterion based on the derived equivalence class relation set. Importance reflects the classification change when the indicator is present or absent in the knowledge base. If the removal of a conditional indicator leads to significant classification changes in set R, indicating a substantial amount of information in that indicator, its importance is relatively high; otherwise, its importance is low. The deviation of the evaluation indicators is calculated as the ratio of the difference between the importance of each indicator and the maximum importance for that life cycle to the maximum importance. In general, if the deviation of a criterion exceeds 90%, the indicator should be removed. The Rosetta software can output multiple sets of indicators, corresponding support degrees, and indicator lengths for each lifecycle stage after reduction. Here, "indicator reduction results" refer to the set of indicators after reduction. "Support degree" indicates the representativeness of the reduced indicator set in the original dataset, with higher support denoting greater coverage of the original dataset. "Indicator length" represents the number of remaining indicators in the reduced indicator set. All these data are directly generated by the Rosetta software. Finally, C17, C25, and C46 are reduced and removed due to deviation exceeding 90%, resulting in the retention of 28 CSFs after reduction, as shown in Table 4.

&lev1;4.2Modeling data acquisitionThe Delphi method is used to assess the degree of association between key stakeholders and CSFs. The Delphi method, also known as the expert survey method, is essentially a feedback anonymous correspondence method. The general process is as follows: after obtaining the opinions of experts on the problem to be predicted, organize, summarize, count, and then anonymously feedback to the experts, solicit opinions again, concentrate again, and then feedback until a consensus is obtained. The questionnaire is mainly composed of three parts: the first part is the introduction of the questionnaire. It mainly includes the background of this survey and the purpose of the data, as well as the description of the questionnaire; the second part is the background information of the questionnaire fillers, which is mainly used to collect the basic information of the fillers and their experience of participating in the renovation, so that it can be used as a reference when collating data; the third part is the identification of the relationship between each stakeholder and the Critical success factors, the relationships to be judged are designed in the form of a structural matrix. This part is the core part of the questionnaire, the data collected as the basis for the subsequent construction of social networks.The nodal relationships were assessed on a five-point Likert scale, with 4.2. Modeling data acquisition

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The nodal relationships were assessed on a five-point Likert scale, with "7″ indicating "very strong impact", "5″ indicating "impact", "3″ for "average impact", "1″ for "very low impact ", and 0 means "no impact". The criteria for determining the node relationship are as follows: (1) if more than 1/2 people choose "7″ and "5″, it means there is an influence between the nodes, and the corresponding node relationship value in the matrix is set to "1"; (2) if more than 1/2 people choose "0″, it means there is no impact between the nodes, and the corresponding value in the matrix is set to "0"; (3) if the number of people choose (1) and (2) is the same, or if the majority of people

Table 3
Decision table using life stage C1 as an example.

Indicator (R) Expert (U)	C11	C12	C13	C14	C15	C16	C17
1	5	4	4	4	4	5	4
2	4	4	5	5	5	5	4
3	5	3	5	4	4	4	3
…	…	…	…	…	…	…	…
20	4	5	4	3	3	3	5

Table 4
Optimized CSF results for existing residential building renovation projects.

Lifecycle stages	Indicator reduction results	Support degree	Indicator length
C_1	C_{11}、C_{12}、C_{13}、C_{14}、C_{15}、C_{16}	100	6
C_2	C_{21}、C_{22}、C_{23}、C_{24}、C_{25}	100	5
C_3	C_{31}、C_{31}、C_{33}、C_{34}、C_{35}、C_{36}	100	6
C_4	C_{41}、C_{42}、C_{43}、C_{44}、C_{45}	100	5
C_5	C_{51}、C_{52}、C_{53}、C_{54}、C_{55}、C_{56}	100	6

choose "3″, a second round of survey will be set up for the disputed option.

In order to improve the reliability and representativeness of the results, a total of 31 experts from different units and different professional fields in Jiangsu are surveyed in this questionnaire. The data collection has a wide range of radiation, involves many industries, and each expert has 2 years or more relevant experience to ensure that the questionnaire results have good accuracy, applicability and reference value. The detailed composition is shown in Table 5.

4.3. Construction of the adjacency matrix

After two rounds of surveys and interviews, experts reached a consensus on whether each stakeholder influences the various CSFs. However, there were differences in opinions regarding the extent of influence among different types of stakeholders within the surveyed regions, as well as among stakeholders from different cities. To balance stakeholder power and interests and to enhance the robustness and potential generalizability of the research findings, this paper does not consider the weight of influence, but only counted the survey results based on the presence or absence of influence. The stakeholder-CSF adjacency matrix established based on the survey results is shown in Table 6, where the horizontal dimension represents stakeholders, and the vertical dimension represents CSFs. If stakeholder S_m has an influence on CSF_n, then the entry (S_m, CSF_n) is marked as 1, otherwise, it is 0 [34].

5. Results and discussion

5.1. 2-Mode network visualization and data analysis

5.1.1. Visualization and data analysis of the overall life cycle 2-mode network

The adjacency matrix in Table 6 is entered into the social network analysis software UCINET 6 to visualize the stakeholder-CSF network relationship under the 2-mode network, and the results are shown in Fig. 2 (squares in the figure represent stakeholders and circles represent CSFs).

Degree centrality, closeness centrality and betweenness centrality are the three most important metrics in SNA analysis. Among them, degree is the most direct metric to portray node centrality in network analysis. The larger the degree of a node means the higher the degree centrality of this node, the more important this node is in the network. Closeness is the degree of proximity between a node and other nodes in the network. The reciprocal of the cumulative shortest path distance from a node to all other nodes indicates proximity centrality. That is, for a node, the closer it is to other nodes, then the greater is its proximity centrality. Betweenness is a metric that portrays the importance of a node in terms of the number of shortest paths through it. The following analysis the degree centrality, closeness centrality, and betweenness centrality metrics of the overall lifecycle 2-mode network.

(1) Stakeholder centrality

The stakeholder centrality analysis of the overall lifecycle's 2-mode network is presented in Table 7. Among all three centrality indicators, Renewal area owners (S2) attain the highest ranking, closely followed by Government (S1). These similarly high values suggest that both entities hold central positions in the network, exerting substantial influence on the success of the renovation project. Property management company (S4) and Community (S3) secure the 3rd and 4th positions in centrality, significantly surpassing other stakeholders. Conversely, indirectly influenced residents (S9) and financial institutions (S8) exhibit low centrality, indicating their peripheral placement in the network and limited influence on the renovation project's success.

Table 7 shows that both Renewal area owners (S2) and Government (S1) have high degree centrality, closeness centrality, and betweenness centrality values, positioning them as the core decision-makers in the social network. Drawing from social capital theory,

Table 5
Composition of questionnaire survey experts.

Occupation	Number	Weight	Related experience	Number	Weight
Government and community managers	6	17.65%	2 years	3	8.82%
Design and construction company manager	6	17.65%	3~4 years	6	17.65%
Financial industry and consulting staff	6	17.65%	5 years	8	23.53%
Experts in relevant research fields in universities	7	20.59%	6~9 years	9	26.47%
Property business managers	6	17.65%	More than 10 years	8	23.53%

Table 6
Stakeholder-critical success factors neighborhood matrix adjacency matrix.

S_m CFS_n	S1	S2	S3	S4	S5	S6	S7	S8	S9	S_m CFS_n	S1	S2	S3	S4	S5	S6	S7	S8	S9
C_{11}	1	1	1	1	0	0	0	0	0	C_{41}	1	0	1	1	0	1	0	0	0
C_{12}	1	1	1	1	0	0	0	0	0	C_{42}	1	0	1	0	0	1	0	0	0
C_{13}	1	1	1	1	0	0	0	0	1	C_{43}	1	0	1	1	0	1	0	0	0
C_{14}	1	1	1	1	0	1	0	0	1	C_{44}	1	1	1	0	0	0	0	0	1
C_{15}	1	1	0	1	0	0	1	1	0	C_{45}	0	0	0	1	1	0	0	0	0
C_{16}	1	0	1	0	0	0	0	0	0	C_{51}	0	0	0	1	0	0	0	0	0
C_{21}	0	0	0	0	1	0	0	0	0	C_{52}	0	1	1	0	0	0	0	0	0
C_{22}	0	1	0	0	1	0	0	0	0	C_{53}	1	0	0	1	0	1	0	0	0
C_{23}	0	0	0	0	1	0	0	0	0	C_{54}	0	1	0	1	0	0	0	0	0
C_{24}	1	1	1	0	1	0	0	0	0	C_{55}	0	0	0	1	1	0	0	0	0
C_{25}	0	1	0	0	1	0	0	0	0	C_{56}	0	1	0	1	0	0	0	0	0
C_{31}	1	0	0	0	1	0	1	0	0										
C_{32}	1	0	0	0	0	0	1	0	0										
C_{33}	1	0	0	0	1	0	1	0	0										
C_{34}	0	0	0	0	0	0	1	0	0										
C_{35}	0	0	0	0	0	0	1	0	0										
C_{36}	0	0	0	0	0	0	1	0	0										

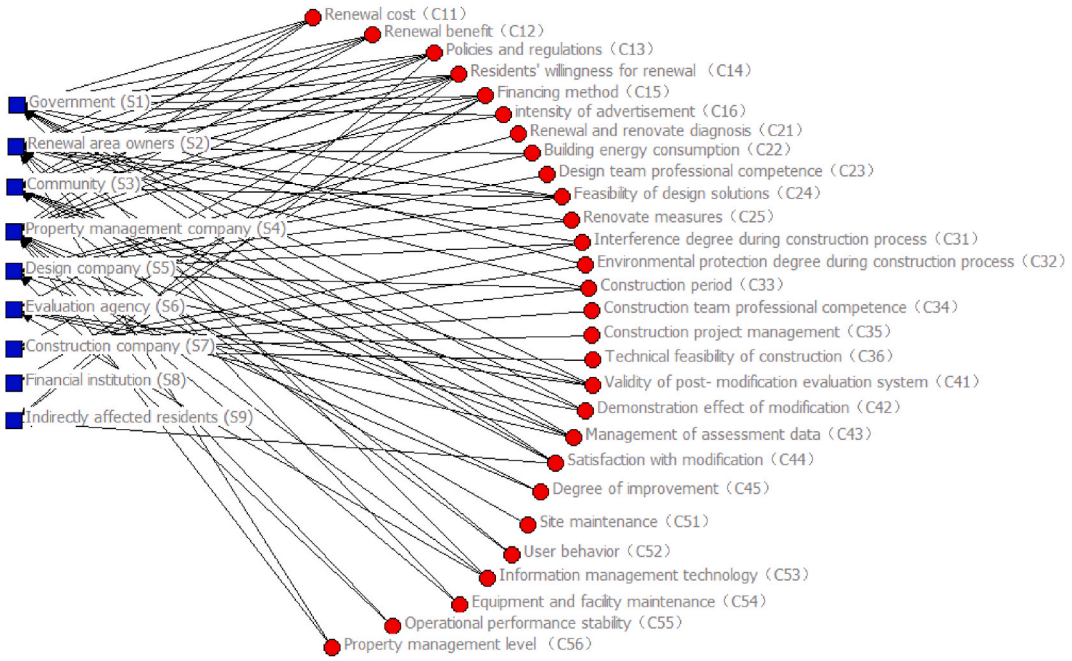

Fig. 2. Overall lifecycle two-mode network of stakeholders and CSFs.

Table 7
Results of stakeholder centrality analysis of overall lifecycle two-mode network.

Stakeholders	Degree		Closeness		Betweenness	
	Value	Rank	Value	Rank	Value	Rank
Government (S1)	0.464	2	0.595	2	0.204	2
Renewal area owners (S2)	0.500	1	0.611	1	0.268	1
Community (S3)	0.421	4	0.579	3	0.194	4
Property management company (S4)	0.429	3	0.579	3	0.200	3
Design company (S5)	0.357	5	0.524	4	0.192	5
Evaluation agency (S6)	0.179	7	0.440	7	0.015	7
Construction company (S7)	0.250	6	0.478	6	0.183	6
Financial institution (S8)	0.036	9	0.400	8	0.000	9
Indirectly affected residents (S9)	0.107	8	0.400	9	0.002	8

Renewal area owners (S2) provide spatial capital. Additionally, the centrality values of Renewal area owners (S2) are closely aligned with those of the Community (S3). The Community (S3), being a grassroots autonomous organization, effectively represents the interests of the residents, relaying their genuine renovation needs and interests for effective feedback, thus playing a vital role in collaborative decision-making. The Government (S1) primarily provides public capital in the form of infrastructure and public services both within and outside the renewal area, holding an authoritative and legitimate position in decision-making. Other key stakeholders such as property management, design units, and construction units participate in decision-making by contributing their exclusive resources (professional skills, funding, etc.) and act as implementers or participants in the decision-making process. Although residents indirectly affected and financial institutions have lower centrality and are on the structural periphery of the decision-making organization, they have potential impacts on the sustainability and inclusivity of urban renewal work. Therefore, their suggestions should also be considered in the renewal and transformation decision-making process.

(2) CSF centrality

CSF centrality of the overall lifecycle 2-mode network are shown in Table 8 and correlation analyses are presented below.

Table 8 shows that the CSF with the highest centrality in the overall 2-mode network is Residents' willingness for renewal (C14), followed by Financing method (C15) and Policies and regulations (C13), which are the core objects that collaborative governance should focus on. The study also found that Feasibility of design solutions (C24), Renewal cost (C11), Renewal benefit (C12), Validity of post-modification evaluation system (C41), Satisfaction with modification (C44) and Management of assessment data (C43) are also high in degree centrality, indicating that these CSFs are also important when conducting collaborative governance.

CSF with the highest intermediary centrality is Financing method (C15), followed by Residents' willingness for renewal (C14), Policies and regulations (C13), Feasibility of design solutions (C24), Renewal cost (C11), Renewal benefit (C12), Validity of post-modification evaluation system (C41), Level of disturbance caused by construction (C31), Construction period (C33) and Satisfaction with modification (C44). The higher the value of intermediary centrality of CSF, the higher the number of times it acts as a bridge for the shortest influence path between nodes in the network. It indicates that the more critical it is in the network, and advancing this CSF requires the cooperation and collaboration of more stakeholders.

CSF with the highest closeness centrality is Financing method (C15), followed by Residents' willingness for renewal (C14). Factors with high closeness centrality are usually associated with core stakeholders and have a huge impact on the network.

5.1.2. Visualization and data analysis of the 2-mode network for each stage of life cycle

The stakeholder-CSF network relationships under the 2-mode network at each stage of the life cycle were visualized, and the results are shown in Figs. 3–7. The blue squares represent stakeholders and the red circles represent CSFs.

From Figs. 3–7, it is evident that the centrality of stakeholders and CSFs undergoes changes during different lifecycle stages of the renovation project. The changes are analyzed as follows.

(1) Investment Decision Stage: This stage is the premise and foundation of successful renovation. The core decision-making entities play a decisive role in whether and how to renovate, thus occupying a central position in the network and holding significant decision-making power. At this stage, decision-makers are more concerned with costs and renovation benefits, making the return on investment a core CSF.
(2) Design Scheme Stage: From the investment decision to the design scheme stage, authority shifts from the core decision-makers to the participating decision-makers. Design units, due to their expertise and authority, become central entities in the network, exerting significant control over decisions. The government transitions from a core to a participating role, primarily playing a supervisory and regulatory function. In this stage, the feasibility of the design scheme becomes the central focus.
(3) Construction Stage: At this stage, construction units emerge as the central entities in the network. As the primary executors during the construction phase, their professional expertise grants them substantial decision-making control, ensuring scientific

Table 8
Results of CSF centrality analysis of overall lifecycle two-mode network.

CSF	Degree	Closeness	Betweenness	CSF	Degree	Closeness	Betweenness
C_{11}	0.444	0.759	0.021	C_{34}	0.111	0.496	0.000
C_{12}	0.444	0.759	0.021	C_{35}	0.111	0.496	0.000
C_{13}	0.556	0.778	0.042	C_{36}	0.111	0.496	0.000
C_{14}	0.667	0.797	0.064	C_{41}	0.444	0.741	0.048
C_{15}	0.556	0.840	0.159	C_{42}	0.333	0.612	0.006
C_{16}	0.222	0.600	0.001	C_{43}	0.444	0.692	0.019
C_{21}	0.111	0.529	0.000	C_{44}	0.444	0.708	0.023
C_{22}	0.222	0.663	0.008	C_{45}	0.222	0.677	0.014
C_{23}	0.111	0.529	0.000	C_{51}	0.111	0.568	0.000
C_{24}	0.444	0.778	0.045	C_{52}	0.222	0.649	0.004
C_{25}	0.222	0.663	0.008	C_{53}	0.333	0.663	0.012
C_{31}	0.333	0.741	0.053	C_{54}	0.222	0.663	0.004
C_{32}	0.222	0.649	0.029	C_{55}	0.222	0.677	0.014
C_{33}	0.333	0.741	0.053	C_{56}	0.222	0.663	0.004

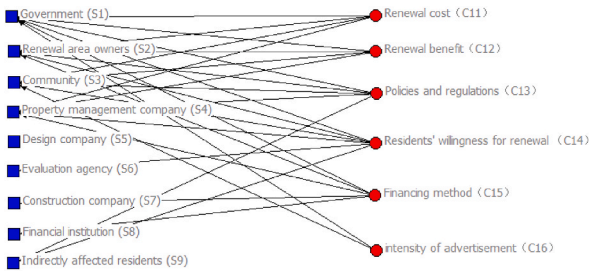

Fig. 3. Stakeholder-CSF relationship at the decision-making stage.

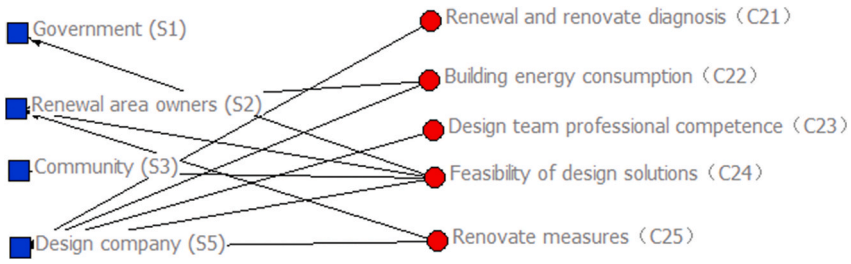

Fig. 4. Stakeholder-CSF relationship at the design stage.

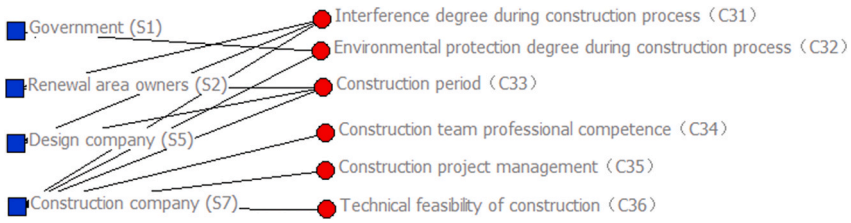

Fig. 5. Stakeholder-CSF relationship at the construction stage.

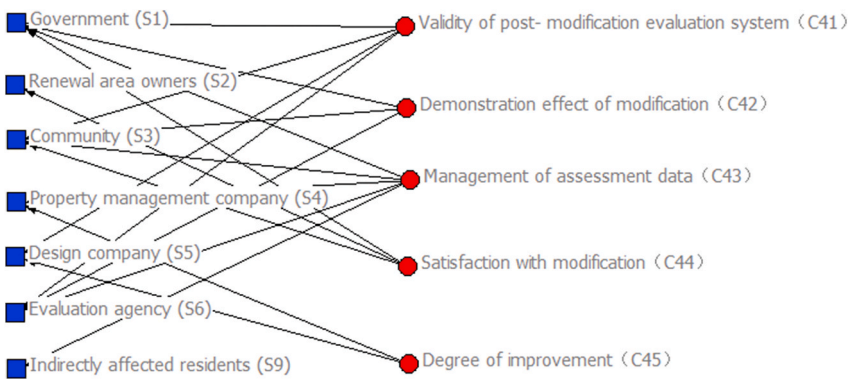

Fig. 6. Stakeholder-CSF relationship at the post-assessment stage.

and rational decisions. For urban residential building renovation, the focus is on minimizing disruption to residents' daily lives, making the degree of construction process disturbance a core CSF.

(4) Post-Renovation Evaluation Stage: To ensure objective, fair, and effective evaluations, professional evaluation organizations need to be fully empowered, placing them at the network's center during this phase. The effectiveness of the evaluation is a core CSF, ensuring that the assessment is meaningful and valuable.

(5) Operation and Maintenance Period: In this phase, the central entities shift to the renovation area owners, property management, and energy service companies. The owners provide funding for operation and maintenance, while property and energy service

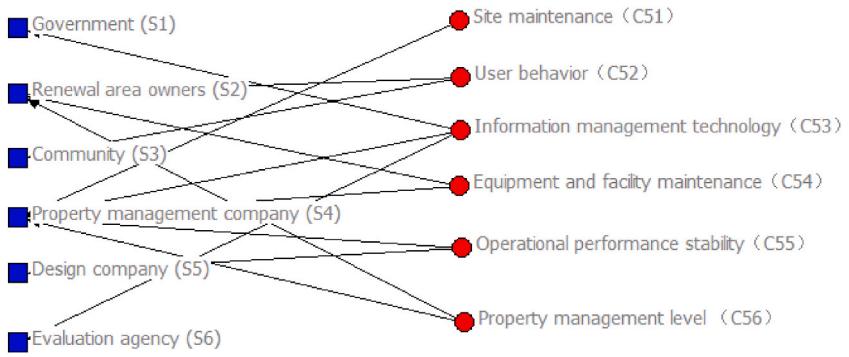

Fig. 7. Stakeholder-CSF relationship at the operation stage.

companies utilize their expertise for effective long-term management of the renovated buildings. Post-renovation, decision-makers focus on the stability of the building's performance in daily use, energy utilization, and conservation, making operational performance stability a core CSF.

The above analysis indicates that, in addition to designing governance mechanisms based on the overall lifecycle, it is also necessary to develop specific process governance mechanisms according to the characteristics of each lifecycle stage.

5.2. Discussion

According to the manifestation of resources, they can be divided into three categories: tangible resources, intangible resources and human resources. Tangible resources generally include material resources (including land, buildings, facilities, machinery, etc.), financial resources and so on. Intangible resources mainly include information resources, relationship resources, rights resources and so on. Human resources refer to the knowledge, abilities and skills of organizational members, as well as their collaborative power and creativity. In the renovation of existing residential buildings, the stakeholder resources are as follows. The government mainly possesses power resources, financial resources and information resources that regulate the behavior and relationship of each subject. Community self-governing organizations mainly possess relationship resources and information resources for communicating with the government and residential organizations, residents and so on. Owners of the transformed community mainly own material resources such as residential buildings and supporting equipment and facilities, as well as the rights and resources brought by their ownership, and their own financial and information resources. Relevant enterprises mainly own human resources such as knowledge, ability and skills, material resources such as production and operation machinery and equipment, financial resources, relationship resources and information resources.

To facilitate the collaborative input of resources by stakeholders supporting different CSFs, it is necessary to construct a collaborative governance mechanism. In this paper, CSFs in Table 8 are ranked according to degree, supplemented by closeness, based on the

Table 9
Results of CSF centrality analysis under the overall two-mode network.

Order	CFS	Degree	Closeness	Betweenness	Influential stakeholders	Collaborative Governance Mechanism
1	C14	0.667	0.797	0.064	S1、S2、S3、S4、S6、S9	Guide stakeholders' willingness and demand for renovation
2	C15	0.556	0.840	0.159	S1、S2、S4、S7、S8	Financing model for stakeholder participation in retrofit projects
3	C13	0.556	0.778	0.042	S1、S2、S3、S4、S9	Social participation in the development of renovation policies
4	C24	0.444	0.778	0.045	S1、S2、S3、S5	A power-adapted collaborative decision-making mechanism for renovation design Solutions
5	C11	0.444	0.759	0.021	S1、S2、S3、S4	A cost-benefit optimization and renovation cost-sharing mechanism based on
6	C12	0.444	0.759	0.021	S1、S2、S3、S4	community development
7	C41	0.444	0.741	0.048	S1、S3、S4、S6	A post-evaluation system for renovation projects with the participation of
9	C43	0.444	0.692	0.019	S1、S3、S4、S6	stakeholders
8	C44	0.444	0.708	0.023	S1、S2、S3、S9	Comprehensive effect of the mechanism.
10	C31	0.333	0.741	0.053	S1、S5、S7	Managing construction disturbance in design-construction collaborative
11	C33	0.333	0.741	0.053	S1、S5、S7	renovation projects.
12	C53	0.333	0.663	0.012	S1、S4、S6	Guidance mechanism for the application of information management technology during the whole life cycle of renovation projects
13	C_{42}	0.333	0.612	0.006	S1、S3、S6	Release guidelines for residential building renovation based on the whole process life cycle

2-mode SNA. This ranking, along with Table 6 and Fig. 2, helps identify the composition of stakeholders influencing the achievement of each CSF. Subsequently, a collaborative governance mechanism aimed at promoting the attainment of CSFs is constructed. The relevant data and the proposed governance mechanisms are presented in Table 9. It should be noted that for the construction of a system that is both comprehensive and focused, this paper does not specifically analyze the 15 CSFs with a degree of 0.222 or below.

(1) Build a collaborative mechanism to guide stakeholders' willingness and demand for renovation

Residents' willingness to renew (C14) is the CSF with the highest centrality in the overall bimodal network and the decision stage network.1 According to the overall bimodal network shown in Fig. 2, the factor is mainly support by Government (S1)、Community (S3)、Property management company (S4)、Evaluation agency (S6)、Indirectly affected residents (S9), and is also closely related to the own cognition of Renewal area owners (S2). Therefore, in order to promote Renewal area owners (S2) to participate in the renovation by providing material resources for their residential buildings and ancillary facilities, the government (S1) should use its power and resources to formulate policies and regulations that provide incentives and constraints, guarantee the rights of Renewal area owners (S2) to make decisions and obtain benefits from the renovation due to their property rights, and guide them to assume their social responsibilities and obligations. The community (S3) should use its relationship resources to strengthen the promotion of the renovation and to be a bridge of communication between all parties, while the property management company (S4) should demonstrate its knowledge, ability, skills and other human resources to raise the awareness and confidence of the renewal area owners (S2) in the effectiveness of the renovation. Indirectly affected residents (S9) can support the work through public opinion. This will form a mechanism to guide owners' willingness and demand for renovation in collaboration with stakeholders, and creates a group atmosphere for renovation.

(2) Establish a financing model for stakeholder participation in retrofit projects

Financing method (C15) holds the second-highest centrality in both the overall 2-mode network and the decision stage network. This critical success factor is primarily supported by Government (S1), Renewal area owners (S2), Property management company (S4), Construction company (S7), and Financial institution (S8). Therefore, the Government (S1) should leverage its power and financial resources to attract stakeholders to invest in financial resources, thereby expanding fundraising channels. For instance, the government can utilize its power resources to create supportive policies, encouraging stakeholders to engage in direct and indirect financing for renovations. Financial resources can be allocated to establish a fund for urban residential building renewal, directing funds towards public infrastructure renovation to guide the process. Market players like Renewal area owners (S2), Property management company (S4), and Construction company (S7) should participate in project financing through direct and indirect investment. Their involvement should be based on the economic benefits of renovation projects and an analysis of supportive government policies, establishing a model of stakeholder participation in project financing to offer financial support for the project's success.

(3) Improve the mechanism of social participation in the development of renovation policies

Policies and regulations (C13) holds the third-highest centrality in the overall 2-mode network. This critical success factor is primarily supported by Renewal area owners (S2), Community (S3), Property management company (S4), and Indirectly affected residents (S9), and it is closely related to the Government's (S1) own capacity. Consequently, the government should establish procedural norms, actively seek advice from stakeholders, and encourage their active participation in shaping renovation policies. Renewal area owners (S2) and Indirectly affected residents (S9) should express their interests fully through public participation, while the Community (S3) should utilize its resources of connections and multiple channels of information to contribute to policy formulation. Management companies (S4) and other enterprises can advocate for their interests through the entrepreneurial participation mechanism in the formulation of enterprise-related policies constructed by the community or the government. This approach will gradually establish a comprehensive social participation mechanism in the formulation of renovation policies, providing practical policy support for the success of the project.

(4) Build a power-adapted collaborative decision-making mechanism for renovation design solutions

Feasibility of design solutions (C24) is the CSF that ranks 4th in overall 2-mode network centrality and 1st in design phase 2-mode network centrality. The factor is mainly driven by Government (S1), Renewal area owners (S2), Community (S3), and is closely related to Design company (S5) is also closely related to the ability of the design company (S5) itself. Since Feasibility of design solutions (C24) has a fundamental influence on the size and distribution of stakeholders' interests, a collaborative decision-making mechanism of the design proposal should be constructed based on the analysis of the power sources of Government (S1), Renewal area owners (S2), Community (S3) and Design company (S5) and their positions and roles in the transformation social network to ensure the balanced coordination of power and interests of all parties.

(5) Build a cost-benefit optimization and renovation cost-sharing mechanism based on community development.

Renewal cost (C11) and Renewal benefit (C12) ranked the fifth CSFs in the overall 2-mode network centrality. These factors mainly supported by Government (S1), Renewal area owners (S2), Community (S3) and Property management company (S4). Since the trend

of urban development for residential buildings is to transform from "residential area planning" to "community planning", Government (S1) should make use of its urban planning power resources and financial resources, and Community (S3) should make use of its relationship resources. Property management company (S4) should make use of its professional knowledge, ability, skills and other human resources in operation and management, and the Renewal area owners (S2) shall make use of its right to maintain and increase the value of material resources to jointly promote the optimization and efficiency of renovation projects from the perspective of the overall development of the community.

Renewal area owners (S2) are the natural beneficiaries of the renovation project, as they own the material resources of the residential buildings and the attached equipment and facilities, while the government (S1) is the beneficiary of the environmental and social benefits of the renovation project as the exerciser of public power. Based on the principle of "who benefits, who pays", both the Renewal area owners (S2) and the government (S1) should invest capital and resources to participate in the collaborative effort. Thus, a reasonable cost-sharing mechanism should be established to ensure reasonable input and sharing of renovation costs.

(6) Establish a post-evaluation system for renovation projects with the participation of stakeholders

Validity of post-modification evaluation system (C41) and Management of assessment data (C43) are the CSFs ranked 7th and 9th in overall 2-module network centrality, and are the CSFs ranked 1st and 2nd in post-assessment phase 2-module network centrality. These two factors are mainly supported by Government (S1), Community (S3), Property management company (S4) and Evaluation agency (S6). Therefore, Government (S1) should use its supervisory and management power resources to establish a sound post-evaluation system for renovation projects, and Community (S3) should use its relationship resources to assist in the implementation of the post-evaluation system, while Property management company (S4) and Evaluation agency (S6) should use their professional knowledge, ability, skills and other human resources and information resources to do the professional work of post-evaluation of renovation projects, and provide a basis for stakeholders to evaluate project performance and perceive the effectiveness of renovation.

(7) Establish a mechanism for managing construction disturbance in design-construction collaborative renovation projects.

Level of disturbance caused by construction (C31) and Construction period (C33) are the CSFs ranked 10th and 11th in overall 2-mode network centrality, and the CSFs ranked 1st and 2nd in construction phase 2-mode network centrality. These two factors are mainly supported by Government (S1), Design company (S5) and Construction company (S7). Based on the fundamental influence of the renovation design plan on the construction plan, Design company (S5) should optimize the design plan by improving its human resources such as professional knowledge, competence, and skills to provide prerequisites for reducing the construction disturbance. Construction company (S7) should also optimize the design plan by improving its human resources such as professional knowledge, competence, and skills and the Construction company (S7) should also reduce the disturbance of the construction process by improving its human resources such as professional knowledge, ability and skills by reasonably selecting its construction machinery and material resources. The Government (S1) should use its management and supervisory power resources to reasonably develop a construction disturbance management system to reduce the level of construction disturbance.

(8) Establish the guidance mechanism for the application of information management technology during the whole life cycle of renovation projects

Information management technology (C53) is the 12th CSF in the overall 2-mode network centrality ranking, and this factor is mainly supported by Government (S1), Property management company (S4) and Evaluation agency (S6). Based on the fact that life-cycle information management can enhance the integrity and systematization of renovation projects information and provide a basis for stakeholders to understand, feedback and highly share project information in a timely manner. The Government (S1) should use its management and supervision power resources to establish a guidance mechanism for the application of life-cycle information management technology in renovation projects. Property management company (S4) and Evaluation agency (S6) should also improve the level and capability of information management technology application by upgrading their professional knowledge, ability and skills and other human resources. Improving the level and capability of information management technology application is beneficial to achieving the company's business goals while promoting the success of the renovation project.

(9) Release guidelines for residential building renovation based on the whole process life cycle

The relationship between stakeholders and the CSFs network under the 2-mode network in each phase of the life cycle shows (Figs. 3–7) that each phase of the renovation project life cycle has its own key factors for project success, and the stakeholders supporting these factors are also different. Thus, a collaborative mechanism for guiding stakeholders' resources input at different stages should be developed based on the whole life-cycle process to ensure the success of the renovation project at both the overall and each stage levels.

6. Conclusions

With the advent of the urban renewal era in an increasing number of countries, projects for the renovation and transformation of old residential buildings will continue to emerge. Only through a systematic analysis of the key success factors in renovation projects

and the promotion of their achievement based on collaborative governance among stakeholders can the success rate of renovation projects be improved, fostering the sustainable development of urban renewal.

This paper identifies 9 stakeholders and 28 CSFs in the retrofitting of existing residential buildings based on the context of Jiangsu, China, and analyzes the complex relationships between life-cycle stakeholders and CSFs using 2-mode social networks in general and in each phase of renovation in order to present the necessity of collaborative stakeholder governance and the principles of collaborative governance mechanism design. The overall 2-mode network stakeholder centrality analysis shows that Renewal area owners (S2) have the highest degree of centrality, followed by Government (S1), Property management company (S4), and Community (S3), indicating that they have greater collaborative governance influence. Factor centrality shows that 13 core CSFs have a more significant impact on the success of renovation projects, with the top 6 being Residents' willingness for renewal (C14), Financing method (C15), Policies and regulations (C13), and Feasibility of design solutions (C24), Renewal cost (C11), and Renewal benefit (C12). In the end, this paper designs nine collaborative governance mechanisms based on the resources owned by each stakeholder as the basis of participation. These include: (1) constructing a collaborative mechanism to guide stakeholders' willingness and demand for renovation. (2) Constructing a financing model for stakeholders to participate in renovation projects. (3) Improve the mechanism of social participation in the formulation of renovation policies. (4) Build a collaborative decision-making mechanism for the design of renovation plans with appropriate power. (5) Build a cost-benefit optimization and renovation cost-sharing mechanism based on community development. (6) Establish a post-evaluation system for renovation projects with the participation of stakeholders. (7) Establish a mechanism for managing construction disturbance in design-construction collaborative renovation projects. (8) Establish the guidance mechanism for the application of information management technology during the whole life cycle of renovation projects. (9) Release guidelines for residential building renovation based on the whole process life cycle. These mechanisms can promote the achievement of the 13 core CSFs and thus guarantee the success of renovation.

Compared with previous studies, the contributions of this study can be summarized as follows: (1) Based on the logic that project success can be achieved when all CSFs are in place, we propose a 2-mode network analysis method to explore the relationship between CSFs and stakeholders in renovation projects, and then clarify the stakeholders and their resources required by each CSF, so as to design collaborative governance mechanisms. (2) Taking Jiangsu, China, as the study area, 2-mode network models are constructed for the renovation project both in general and at each stage, and nine collaborative governance mechanisms are designed based on the model analysis results, which provide a reference for the relevant work carried out in the region. (3) Although the findings of this paper are based on the analysis results of the Jiangsu, China, the research methods and ideas are replicable and thus have reference value for the development of related research in other regions.

Although this study systematically summarizes the key success factors of residential renovation and constructs a multi-agent collaborative governance mechanism based on the resource inputs required for these key success factors, the governance mechanism developed in this paper is still conceptual. It does not delve into the details of its formation mechanism, implementation tools, and application scenarios, nor does it explore strategies for optimization and adjustment in dynamic environments. The construction and optimization of a collaborative governance mechanism for the renewal and renovation of existing residential buildings is a dynamic process. As rational "economic agents", the parties involved in collaborative governance have unique resources and goals. However, in order to realize their own goals, they also need to rely on the support of other parties' resources, forming a close-knit relationship. This interdependence promotes the dynamic evolution of the game between multiple subjects, and ultimately reaches the goal equilibrium and the rights and interests of the fitness, so as to realize the resource sharing and complementary advantages among multiple subjects. More attention should be paid to the methods and procedures of decision-making based on the idea of power change and group consensus. The close coupling of these two helps to better cope with the dynamic interactive group decision-making process with multiple attributes and multiple stages. Such research not only helps to better understand the behavior of all parties in collaborative governance, but also provides a strong support to motivate multiple parties to reach agreement more efficiently and promote the smooth progress of projects. Overall, in-depth research in this direction not only helps to optimize the collaborative governance mechanism, but also helps to better realize the synergy between the parties in the project, and ultimately promotes the successful implementation of the renewal and renovation work.

Additionally, the identification of key success factors for residential renovation in urban renewal and the construction of collaborative governance mechanisms constitute a complex and dynamic systems engineering task. While the collaborative governance framework presented above is derived from extensive studies and expert research focused on several cases within the Jiangsu region of China, it is noteworthy that the composition of life cycle stages, stakeholders involved at each stage, and the resource inputs required for renewing and renovating existing residential building projects remain fundamentally similar across different regions or countries. Consequently, through a meticulous analysis of local social, political, economic, and cultural characteristics, coupled with an understanding of the stages in urban renewal development, we can pinpoint potential variations in the rights and resources of stakeholders and their plausible impact on critical success factors. Building upon this foundation, we have the flexibility to tailor and adapt the aforementioned governance mechanism framework to suit specific local contexts This requires targeted research based on the socio-economic environmental conditions of different countries and regions, as well as the development stages of urban renewal. Therefore, selecting typical countries and regions as research areas, studying the key success factors and collaborative governance mechanisms of typical residential renovation models, and forming contextualized governance mechanisms along with their implementation tool combination strategies and dynamic optimization and adjustment pathways, are directions for future research expansion.

Data availability statement

Data will be made available on request.

CRediT authorship contribution statement

Ling Shen: Writing – review & editing, Methodology, Investigation, Conceptualization. **Lingyi Tang:** Writing – review & editing, Writing – original draft, Validation, Investigation, Formal analysis. **Yue Mu:** Writing – original draft, Investigation, Formal analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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